MOTIVATION, KRECH HYPOTHESIS BEHAVIOR, AND ADAPTABILITY

By

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CHAPTER I

INTRODUCTION

This study was primarily concerned with determining how hypothesis behavior in the hooded rat varies with changes in motivation. It was also concerned with finding out what relation such hypotheses have to adaptive behavior, e.g., are animals that show certain types and numbers of hypotheses more adaptable or flexible than others? And finally, it was concerned with the relation between motivation and adaptability.

Hypothesis behavior is a term first used by Krechevsky (1932a) to describe the apparently non-random, systematic attempts of rats to solve an insoluble linear maze problem. It is necessary to maintain a careful distinction between the behavior of the animal in the experimental situation and the implications of the experimental results. Hypothesis behavior refers to a particular type of behavior which occurs in a specific situation. The behavior is a pattern of choices made in relation to specific cues in an insoluble discrimination maze. When the pattern of choices differs from a random

level by a certain amount, hypotheses are said to be formed. Hypothesis behavior and hypotheses are terms which have meaning only when the apparatus, the cues, the pattern of choices, and the statistical level are understood.

Hamilton (1911) noticed in the course of a trial and error learning experiment that rats and other animals make apparently systematic attempts at solving problems that cannot be solved; they may go consistently to the right, or left, or to the last place found successful, and so on. Lashley (1929) also noted this feature of behavior in discrimination problems. He indicated that while there was no experimental technique available at that time to investigate this behavior, these "attempted solutions" probably represented a significant aspect of the learning process. Lashley's observations served as at least a partial basis for Krechevsky's investigations; Krechevsky's experiments were designed to provide the lacking experimental technique. In one of his earliest published works he states, "The data from the present experiment have been examined in the light of Lashley's suggestion and an attempt has been made to devise a method for the objective determination of the validity of that suggestion." Krechevsky concluded from this study that "...it is shown quite definitely in the presolution period that...the animal is engaged in bringing to perfection various

attempted solutions.... In the light of the evidence presented here it is suggested that the helter-skelter unorganized trial and error response as a description of the early part of the learning process is invalid, and that we must change our description of the learning process so as to recognize the existence of organized and systematic responses at all stages of the process." (1932a, p. 43)

Krechevsky's interpretations were directed against the prevalent behaviorism which used trial and error learning - and later the conditioned reflex - as a model. Boring (1950) characterized both of these models as eliminating the need for integrative principles such as organization or insight. Tolman, under whom Krechevsky was studying for his doctorate, was then developing his theory of purposive behaviorism. This theory emphasized the cognitive, intellectually organized aspects of learning. Krechevsky's work with hypothesis behavior served both as a fundamental tenet of the Tolmanian system and as experimental evidence against an anti-insight behaviorism.

Krechevsky's 1932b experiment formed the basis for all the later work in this area. The maze which he designed was a four unit discrimination apparatus which could not be solved (see Figure 1). The animal was confronted by four choice-points between the start box and the goal box. A

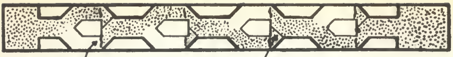

Fig. 1.-Floor Plan of the Krechevsky Hypothesis Maze.

This diagram shows the maze as it appears on trial 7. An animal following a visual-dark hypothesis would choose alleys in the order left, left, right, right.

correction method was used at each choice-point and the reward was available in the goal box at the completion of every trial regardless of the correctness of the animal's four choices. Krechevsky used a 23-hour food deprivation schedule; a cube of bread soaked in milk was used as the incentive. At each choice-point there were two alleys, a right and a left, between which the animal could choose. Over each alley was an electric light, but only one side was illuminated. The animal might choose on the basis of spatial cues (right, left) or visual cues (light, dark). A curtain at the end of each alley prevented the animal from seeing a swinging door which could be locked to either side, thus preventing the animal from using one or the other alleys. One alley of each of the four units was always locked. When the animal chose an alley which had an open door, it went through to the next unit. When the

animal chose an alley with a locked door, it was forced to reverse its course and go through the alley on the other side.

The animal was given twelve trials each day. On every trial the lights and doors were shifted in such a way that: 1) the lights and open doors were on either side of the choice-point equally often, and, 2) the use by the animal of any of the eight hypotheses which Krechevsky identified would result in encountering the same number of open and locked doors. (See Table 1 for the trial order positions of lights and doors.)

TABLE 1

THE KRECHEVSKY TRIAL ORDER FOR THE POSITION OF OPEN DOORS AND LIGHTED ALLEYS ON THE TWELVE DAILY TRIALS IN THE MAZE

Trial	1	2	3	4
Door Open	L L R L	R R R L	R R L R	L L R R
Light On	R L R L	R L R R	L R R R	L R L L
Trial	5	6	7	8
Door Open	R R L L	R L L L	R L L R	L R L L
Light On	R R L L	L L R R	R R L L	R L L L
Trial	9	10	11	12
Door Open	L R R L	R L R R	L L L R	L R R R
Light On	L L L R	L R R L	R L R R	L R L R

Two major types of hypotheses were distinguished, those based on visual cues and those based on spatial cues.

> Among the visual hypotheses, an animal may systematically choose the lighted alleys (a "Light Hypothesis") or the dark alleys (a "Dark Hypothesis"). Sometimes an animal tends to choose an alley in terms of the similarity of its visual characteristics to the immediately preceding "correct" alley (e.g., choosing a lighted alley if the previous lighted alley had proved correct). This behavior is termed a "Perseverative Visual Hypothesis." Conversely, the rat may show an "Alternating Visual Hypothesis"....
>
> The other general categories of hypotheses - spatial - also has four possibilities... there are "Right", "Left", "Perseverative Spatial", and "Alternating Spatial" hypotheses. (Rosenzweig, et al. 1958, p. 375)

It is possible to invent any number of systematic patterns of choice - hypotheses - for the animal, but Krechevsky compared the animal's choices for correspondence to these eight. The equivalent of the Spatial hypotheses, -Right, -Left, and -Perseverative, and the Visual hypotheses, -Light and -Dark, had already been noted by previous investigators. The other hypotheses appear to be logical extensions of these five.

If the animals made completely random, unsystematic responses at each of the 48 choice-points (four choices on each of twelve trials), they would choose - on the average - 12 right-lighted, 12 right-darkened, 12 left-lighted, and 12 left-darkened alleys in some random order. A theoretical random animal would be expected to have an average of 24

choices to each of the four cues (Left, Right, Light, Dark). Krechevsky defined non-random, systematic behavior - his hypothesis behavior - as being present when the animal chose one of the eight alternatives with a frequency significantly greater than the theoretical random mean of 24. The level of significance which he chose was three standard deviations above the mean. This amounts to 34.39 choices out of 48.

With this criterion, Krechevsky found that most of his animals formed hypotheses and from these early studies he concluded that "...the presence of systematic forms of behavior in such a situation is to be interpreted to mean that these systems were determined not as something forced _ab extra_ by the situation, but as something originating from the animal himself" (1932b, p. 45). He suggested that "...descriptions of the lower animals' behavior as consisting of "stereotyped," "haphazard," "non-insightful" responses are to be attributed not to a lack of insight on the animals' part but rather to a lack of insight on the experimenter's part" (1932b, p. 63).

Over the next several years, Krechevsky continued his investigation of hypothesis behavior. In one of these studies (1933b) he used animals from Tryon's "bright" and "dull" strains and found that the "bright" animals had more spatial hypotheses and the "dull" animals had more visual hypotheses. Another study examined some of the conditions

under which animals give up or persist in hypotheses. Rats which had formed hypotheses were divided into three groups. One group then found the maze solvable in conformance with the hypothesis each animal was exhibiting; the second group had the maze solvable for a different hypothesis; a third group had the incentive removed as soon as an hypothesis was demonstrated. The first group persisted in their original hypotheses, the second group changed hypotheses to the correct solution, and in the third group more than fifty per cent of the animals refused to run at all. This study was integrated with a further exposition of Tolman's theory and Krechevsky's most important conclusion was that "...if any behavior-act can be established as docile and purposive, 'hypothesis'-behavior is definitely so" (1933a, p. 442).

Krechevsky began a series of investigations on the relation of hypothesis behavior to the structure and function of the brain (1935, 1937a, b, c). He found that cortical lesions decreased the number of different hypotheses an animal might use, but increased the number of days an animal would use the same hypothesis. He also found evidence that this behavior was not related in simple fashion to the amount of cortical damage, but to both the amount and locus of damage. One area (occipital lobe) he called V because few animals made visual hypotheses when it was damaged. Another area (somesthetic) was identified as S, because of

a similar effect on spatial hypotheses. Damage to both areas tended to result in spatial hypotheses.

Krechevsky published no more articles on hypothesis behavior until recent years. Hypothesis behavior served as the prototype for other Tolmanian concepts such as means-end-readiness, and Krechevsky began experimentation in other areas. Also, while hypothesis behavior was directly related to the controversy over the continuous or discontinuous nature of learning, the hypothesis behavior maze was not readily adaptable to investigating this problem. Krechevsky designed other pieces of apparatus for this purpose.

The only critique of hypothesis behavior which exists in the psychological literature is that provided by Witkin (1942). Witkin noted that hypothesis behavior is not typical of solvable problem situations, but rather of situations for which no solution can be found. He found the same type of behavior in the Krechevsky hypothesis maze when the doors were completely removed (free-choice) as when the doors were locked according to Krechevsky's insoluble pattern; the behavior was not found when a solvable pattern was used. He questioned the adaptive or purposive nature of hypotheses, since animals shifted hypotheses in a free-choice situation although the first hypothesis - or no hypothesis at all - was equally adaptive.

He also questioned Krechevsky's interpretation of the cortical lesion studies. "Habits having a far simpler basis than 'hypotheses' cannot be performed after extensive cortical lesion. Yet every animal submitted to decortication showed systematic behavior in linear 'insoluble' situations, pointing to the relatively simple basis of these responses" (pp. 566-567). Witkin suggests that the changes in behavior resulting from differential locus of lesions may be the result, essentially, of removing from the animal the capacity to receive particular sensory cues within the maze. Witkin concludes, "The 'hypotheses' concept and the system of which it is a part arose in opposition to the crudely mechanistic conceptions which have gained prominence.... As opposed to such piecemeal conceptions, the 'hypotheses' concept attempted to present the learning process as orderly, organized, and predictable, and pictured the learner as a more active participant in determining the character of the final learned habit. This...is a very desirable end, but since...the 'hypotheses' concept swings to an extreme where it is beyond the bounds of evidence, it constitutes a very weak kind of opposition..." (p. 567).

Spence also had been critical of Krechevsky's interpretations, "Contrary to the belief of certain writers, ... there has been no disagreement concerning the behavioral facts.... Agreement ceases however, over attempts at further

interpretation of the phenomena" (1945, p. 253). In an early theoretical paper on the nature of discrimination learning, Spence (1936) demonstrated that perseverative behavior - similar to hypotheses - was compatible with the Hull-Spence system. Hypotheses were considered as a phenomenon dependent on learning processes before the correct learned response became manifest; as such, it is a phenomenon characteristic of a pre-solution period. At a later time Spence distinguished between this perseverative _pre-solution_ behavior and the hypotheses which Krechevsky found in an _insoluble_ maze, "...these pre-solution phenomena appear to be a typical example of what has been described as trial and error learning, while hypotheses are far from what...(I understand)...by the terms insightful and intelligent. Only _persistent_ non-adaptive responses can attain the distinction of being hypotheses--for, in order to classify as a hypothesis, a response, although ineffective, must continue to be persisted in a certain minimum number of times. A maladaptive act which is speedily (intelligently?) abandoned cannot ever be a hypothesis" (1940, p. 287). Both forms of perseverative behavior are, for Spence, predictable from his theoretical framework. As a pre-solution phenomenon, the hypothesis is expected to be replaced by the correct response without any intermediary hypotheses. In the insoluble problem situation,

the development of hypotheses (or the complete nonoccurrence of them), shifts between hypotheses, and the persistence of hypotheses, are all theoretically explainable post hoc providing certain assumptions regarding initial response strengths and reinforcements can be made. Unfortunately, the Krechevsky hypothesis maze does not lend itself to an empirical test of the Spence position.

There was no further work on hypothesis behavior until 1954 when Krech[1], Rosenzweig, and Bennett began publishing the results of a series of experiments which correlated brain chemistry with adaptability. Despite the earlier criticisms of hypothesis behavior, this technique was used as the measure of adaptability. Two changes were made in this measure. First, a reduced level of significance was used as a criterion of hypotheses (33 rather than 35 choices of the 48 occurring each day), and second, Krechevsky's (1933) spatial-visual Preference Score was also used. This Preference Score provided a continuous scale of relative preference for either visual or spatial modalities within each animal. It is computed in this fashion: 1) the number of choices in each of the eight hypothesis alternatives is determined for an animal for a

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[1]Krechevsky changed his name to Krech.

given day; 2) the deviation in per cent of these eight numbers from fifty per cent is computed; 3) the percentages based on spatial hypotheses are given positive signs, the visual percentages are given negative signs, and the eight percentages are then algebraically added.

In a later study by Rosenzweig, et al. (1958), the results indicated that the amount of cholinesterase (ChE) significantly increased from the visual area (V) to the somesthetic area (S) to the motor area (M); the amount in all areas declined with age. When visual preference animals were compared to those with spatial preferences, the ChE rate of decline was found to be very rapid. The authors were using ChE as a measure of acetylcholine (ACh) metabolism, and inferred from these results that ACh metabolism is related to adaptive behavior patterns.

Such an inference necessitates two assumptions. One concerns the ChE-ACh relation and is a chemical problem; the relation of hypothesis behavior to adaptability is properly a psychological problem which the authors justify as follows:

> ...we believe that animals that show a spatial Preference Score are more adaptive than animals showing a visual Preference Score. We make this interpretation for the following reasons: (1) As we have already pointed out, our test is designed to measure the animal's perceptual selectivity. (2) We next assume that adaptive behavior is correlated with the ability of the animal to "pay attention to" various stimulus aspects of its

> environment when confronted with a problem. Thus, for example, Tolman stresses the importance of determining the "...conditions which favor relatively rapid shifts in the dimension of discrimination of a sign or of a significate..." in understanding differential effectiveness of performance. (3) In our maze, under the conditions of training that we have used, almost all animals show a light-going preference on their first few trials... Achieving a spatial Preference Score therefore requires that an animal ignore the dominant illumination cue and pay attention to the less obvious cue of location in space. In other words, an animal that develops a spatial preference shows readier "shifts in discrimination" than an animal whose behavior remains controlled by the visual cues. (1958, p. 389)

While this is an attractive line of reasoning, there are certain disturbing features. Whether a continuous Preference Score or the discrete category, hypotheses, is used, the criticisms of Witkin and Spence remain pertinent and have not been answered. In addition, very little is known about hypothesis behavior and the variables affecting it; the phenomenon has been a theoretical pawn and there have been no investigations since Witkin's efforts twenty years earlier. Despite the occasional criticisms and the lack of a sound empirical foundation, Krech treats hypothesis behavior as definitely adaptive, cognitive, attempted solutions. He receives some support for this position from standard reference works which review his work; hypothesis behavior is uncritically treated as evidence for attempted solutions on the part of the rat (see Munn, 1950, pp. 250-253, 333; Stevens, 1951, pp. 312, 744, 774-776; Osgood, 1953, pp. 445-446; Hilgard, 1956, p. 201).

The results of experiments are sometimes discussed with reference to hypotheses. Petrinovitch and Bolles investigated the effects of <u>kind</u> of deprivation on learning. Using hungry and thirsty rats in a single-unit-T-maze, they found that when the goal was alternated on every trial the food-deprived animals were better, but when the goal remained fixed, the water-deprived animals were superior. They related their findings to Krechevsky's (1937) report that normal animals alternate and vary their hypotheses. The authors suggested "In the light of the present experiment, it is possible that his data do not pertain to 'normal' animals, but only to normal <u>hungry</u> animals. In general, our results suggest that in any study of variability or stereotypy in behavior, the nature of the 'drive' used must be carefully considered" (1954, p. 452).

Cognitive theorists have been attaching increased importance to drive states. Tolman (1949) has modified his earlier position and suggested that drive reduction may be necessary for some types of learning. Similarly, Krech no longer holds to a strict cognitive theory of learning. He writes "It is quite obvious, if you examine many of the theories extant in psychology today, that these theories do not rest content with motivational constructs only, or with cognitive constructs only, but require <u>both</u> sets of constructs.... The belief in the <u>interaction</u> among the

hypothesized cognitive and motivational processes is certainly one of the most outstanding...current trends in... theories today" (1951, p. 114).

The effect on hypotheses of manipulating drive remains unknown. Motivational variables are known to facilitate or decrease performance levels, but it is difficult to apply the motivational literature to hypothesis behavior for several reasons. First, most of the experiments are more applicable to motivational phenomena or theory. Second, the general nature of hypothesis behavior is unknown. And third, data in hypothesis behavior experiments are not directly comparable to data in the usual learning experiment with only one solution.

The present study was directly concerned with these problems. It was designed to determine empirically the relationship between the hypotheses formed by an animal and another measure of that animal's adaptability; it was also designed to explore the effects of motivation on hypothesis behavior and adaptability.

The following research hypotheses were advanced:

1) The type of hypotheses and the frequency with which they are formed is a function of both the level of motivation and the type of motivation.

Three major characteristics of hypothesis behavior could vary as a function of motivational level; these may be

stated in question form:

a) Do animals at a low motivational level form fewer, or more, hypotheses than animals more highly motivated?

b) Do animals characteristically form visual hypotheses at one level of motivation, and spatial hypotheses at another?

c) Is motivational level related to shifts between types of hypotheses?

Petrinovitch and Bolles had suggested that food deprivation might lead to more variation in hypothesis behavior than water deprivation. Accordingly, when level of deprivation is held constant, the following statement will be tested:

2) Do food deprived animals show more shifts between hypotheses than water deprived animals.

The establishment of equivalent levels of motivation in two different modalities, food and water, presents difficulties in both laboratory technique and research design. True equivalence is impossible to attain since hunger and thirst are different experiences. An effective equivalence may possibly be approached by using equivalent operational definitions. The more usual approach of using hours of deprivation would not prove to be a satisfactory procedure; Stellar and Hill (1945) observed that rats may adjust their water consumption, within a limited time of access, to fit

their deprivational state. Brown (1961, pp. 71-74) presented data which leads to the same conclusion. The method which was used in the present study determined the ad libitum food or water intake for a pilot group of animals and then provided that fixed percentage of such an amount which would result in equivalent running speeds in a straight runway. The experimental animals were also weighed just before this limited amount deprivation schedule was started, and, immediately after it ended; this measure provided an additional means of defining motivational level.

3) The adaptability of animals is related to the type and frequency of the hypotheses which they display.

Rosenzweig, Krech, and Bennett (1958) have argued that spatial preferences and hypotheses, and shifts of preference and hypotheses, represent more adaptable behavior since the animal has given up responding to an initial (apparently more dominant) aspect of the situation. The measure of adaptability used in the present study involved a similar logic; the animal was presented with the doors and lights of the hypotheses maze arranged so that one of the hypothesis alternatives was solvable. When criterion was reached, the maze was adjusted for solution of a second hypothesis alternative. Adaptability was thus equated with the number of trials to adopt new modes of response as they became more efficient. The appropriate questions are:

a) Do animals that demonstrate spatial hypotheses and preferences take fewer trials to solve the problems than animals with visual hypotheses and preferences?

b) Do animals that have many hypotheses take fewer trials to solve the problems than animals with few or no hypotheses?

c) Do animals that shift hypotheses and preferences take fewer trials to solve the problems than animals that do not shift?

4) The adaptability of the animals is related to the type and level of motivation.

The Yerkes-Dodson (1908) law holds that optimal motivational level is inversely related to problem difficulty; in the present experiment problem difficulty was not effectively manipulated, therefore, according to this law an optimal level of motivation should be apparent. The positions of Duffy (1951, 1957) and Malmo (1957), are also consistent with this. Brown (1961, p. 94), however, found equivocal results in the area of discrimination learning and concluded that further studies were "urgently needed." The relationship can be posed as the following question:

a) Does a linear relation exist between motivational level and number of trials to solve the problems such that increased motivational level results in fewer trials?

CHAPTER II

PROCEDURE

The general experimental procedure as described by Krechevsky (1932b), and Rosenzweig, Krech, and Bennett (1958) was followed with certain exceptions. These exceptions were a difference in kind and amount of incentive, a slight modification of the maze, and a slightly higher criterion for determining hypotheses. The criterion was placed at 36 choices out of 48 for the following reason: Since each animal had a number of days on which to be scored for hypotheses, the level of significance should be adjusted accordingly. Similarly, the scoring of each animal's daily responses for hypotheses increased the likelihood of finding hypotheses in direct proportion to the number of alternative hypotheses. The four alternating and perseverating hypotheses were not scored so the level of significance was not adjusted to include these data in the determination of hypotheses. Significance levels were adjusted to remain for each animal at $P < .01$ (see Ryan, 1959) in consideration of nine days opportunity to form an hypothesis and four scorings of each day's behavior (spatial -right, -left, and visual -light, -dark).

Subjects. Subjects were 32 naive male hooded rats, varying in age from 92 to 127 days at the start of the experiment. Of this group, one animal was lost from the experiment due to escape from the cage and an undeterminable amount of eating. All animals were housed individually. Water-deprived animals had *ad libitum* Purina rat pellets; food-deprived animals had *ad libitum* water. They were maintained on a 12 hour light-dark cycle in an air conditioned room which had a mean temperature of approximately 78° F.

Apparatus. The standard Krechevsky hypothesis maze was used, modified with five guillotine doors to prevent retracing among the start box, goal box, and discrimination units. The top was covered with window screening painted with aluminum paint to reflect the interior light of the maze and reduce room cues. Determining each animal's choices by mirrors proved unsatisfactory, and direct observation through the screen was used. The maze was placed on a table at the side of a small room. The only light came from the apparatus itself and a 7½ watt bulb suspended over the goal box. This light permitted the experimenter to observe when the animal had reached the goal box and to record the animals' responses. The straight

runway which was used in the pretraining period was similar to the hypothesis maze but with the center sections removed so that no alleys were formed. The guillotine doors were retained and curtains were hung at the three center doors to provide habituation for the animals.

Procedure. Animals were treated in groups of about eight, with random assignment to each condition. The animals assigned to the food-deprivation category (FD) were placed on *ad libitum* powdered Purina rat chow and water schedules; animals in the water-deprivation category (WD) received the same treatment except they were given pellets rather than powdered food. After a four-day adjustment period, measurements of each animal's food or water (as appropriate) consumption was taken for 14 days. At the end of this time the average daily consumption was computed and the animals were weighed.

A pilot study had indicated that 65 per cent of the *ad libitum* food intake and 70 per cent of the *ad libitum* water intake would result in approximately equivalent running times in a straight runway; similar results were found for a 45 per cent food and a 50 per cent water level. Therefore those four levels were adopted. The animals were placed on the appropriate schedule one day prior to the start of the pretraining trials and remained on these diets until the conclusion of the experiment.

Pretraining. The animals were given 5 trials the first day, 5 trials the second day, and then 10 trials each day for nine successive days; the animals were run every 24 hours. The incentive was approximately 0.1 gram of powdered chow or 0.1 c.c. of water, as appropriate. The incentive was taken from each animal's daily ration.

Hypothesis trials. The animals were given 6 trials on both the first and second days, and 12 trials each of the successive eight days. The Krechevsky order (see Table 1) was followed. After the final day's trials within the hypothesis maze were completed, the hypotheses for each animal were computed. Weights were obtained for each animal.

Adaptability trials. On the basis of each animal's hypotheses and membership in the four experimental groups, a decision was made as to which of two visual problems and two spatial problems were to be solved. The criterion for solution was the same as for hypotheses; however, whereas hypotheses were computed on the basis of an animal's daily performance, these trials were counted serially without respect to the termination of each days trials; such a procedure is necessary to prevent grossly unequivalent amounts of practice. An animal was considered to have reached criterion when it first attained 36 out of any 48 consecutive choices which were correct; animals that reached criterion on the first, second, or third choice-points of a

trial were allowed to finish that trial and attain the incentive.

Roughly half of the animals which had made visual hypotheses were assigned spatial problems first; spatial hypothesis animals were treated similarly. When animals had made both types of hypotheses, or none, the assignment was made on the basis of the dominant preference. In all cases, the assignment of any problem within either stimulus modality was opposite to that animal's dominant preference.

The number of daily trials and the incentives remained the same as in the latter part of the hypothesis maze experiment. At the conclusion of the first problem, each animal was immediately shifted to the second problem on the next trial. The scores were each animal's total number of trials to solve both problems.

CHAPTER III

RESULTS

This study was concerned with certain relationships between motivation, hypothesis behavior, and adaptability. Two semi-independent measures of motivation were used. First there was a deprivation schedule providing for restricted amounts of food (FD) or water (WD) at two different levels, moderate and severe. Second, a measurement of body weight change (BWC) over the course of the experiment was obtained.

Since the experimental design required equivalent levels of motivation in the _FD_ and _WD_ groups for testing certain hypotheses, evidence concerning this equivalence will be presented first. Percentages of _ad libitum_ food and water had been chosen to obtain equivalent running times. Speed of running was thus used as a criterion of equivalence. The concept of equivalence can be assumed to have been validly met if it can be shown that the deprivation schedules establish equivalent running times within each level of deprivation.

There are two sources of running time data in the experiment, one from the training trials and the other from

the trials in the Krech apparatus. Response time data were available from 19 animals during the training trials to use as a check against this method. These data, presented in Table 2, showed that only a slight degree of equivalence existed between each of the moderate and each of the severe groups. These data were obtained in a straight runway and were therefore similar to the conditions of the pilot group. However, it is of more pertinence to determine whether equivalent running speeds existed at the time of the hypothesis behavior trials.

TABLE 2

MEAN RUNNING TIME IN SECONDS IN THE TRAINING TRIALS
(Days 3 through 10, N = 19)

	Deprivation	
Level	Food	Water
Moderate	23.9	17.7
Severe	7.6	15.6

Response time data for a sample of 20 animals in the hypothesis maze are presented in Table 3. It will be noted that the moderate FD and severe WD groups were approximately equivalent, but the other groups occupy extreme positions. This indicated that type of deprivation, food or water, was possibly confounded with level of motivation. Analysis of variance established that such

TABLE 3

MEAN RUNNING TIME IN SECONDS IN THE HYPOTHESIS MAZE

(Days 1-9, N = 20)

Level	Food	Water
Moderate	32.1	49.2
Severe	20.4	35.2

confounding did take place. According to the original experimental procedure, a significant difference in running time should be found for the level of motivation variable (since the restricted diets were deliberately chosen to produce different running times). As the summary in Table 4 indicates, animals differed significantly ($P < .005$) in level of motivation as measured by running time level. However, these restricted diets were also deliberately chosen with the intent of producing no significant difference between running times on the type of deprivation variable. Here, unfortunately, they also differed and this difference is significant ($P < .001$). Clearly, testing the experimental hypotheses relating to the food-water variable would introduce motivational level as a contaminating factor.

TABLE 4

ANALYSIS OF VARIANCE ON THE EFFECTS OF TYPE AND LEVEL OF DEPRIVATION ON RUNNING TIMES IN THE HYPOTHESIS MAZE

(X' = log X transformation)

Source	d.f.	M.S.	F	P <
Type (Food-Water)	1	.230	20.35	.001
Level (Moderate-Severe)	1	.138	12.21	.005
Type x Level	1	.004	.35	
Error	16	.011		
Total	19			

Another indication that equivalence did not exist was found when the mean BWC was computed for each of the cells. Table 3 with running time data and Table 5 with mean body weight changes reflect the same general trend. This suggests that the two measures are correlated. This turned out to be true, with a rank order correlation of $\rho = .680$ ($P < .01$). Because of this correlation, per cent of BWC, rather than the dichotomous Moderate-Severe categories, was used as the indicator of motivational level in further analysis of the data.

TABLE 5

MEAN PER CENT OF BODY WEIGHT CHANGE OVER THE COURSE OF THE EXPERIMENT. (N = 31)

	Deprivation	
Level	Food	Water
Moderate	-13.1	-1.8
Severe	-28.9	-8.8

To summarize the results obtained so far,

1. The desired two equivalent levels of motivation were not attained, since type of motivation was contaminated by level of motivation.

2. Per cent of BWC was significantly correlated with running time and was used as the independent variable representing motivational level.

Tests of the Hypotheses

A. The effect of varying motivational level.

The hypothesis was advanced in the introduction that the hypothesis-behavior of the animals would be a function of level of motivation. It is apparent from Figure 2 that varying motivational level induces major changes in both the gross amount and type of hypothesis behavior, spatial (S) or visual (V). The more negative the BWC, the more S hypotheses the animal forms.

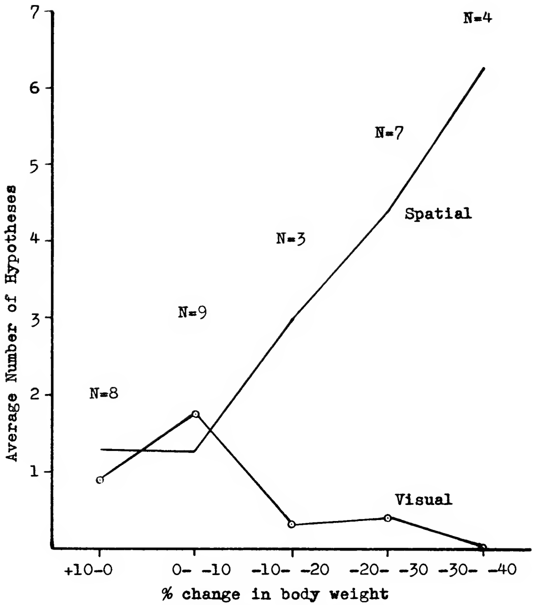

Fig.2.-Number and type of hypotheses formed as a function of body weight (totals of all hypotheses within a class interval, divided by the number of subjects, N, of the class.)

The form of the data and the nature of the inquiry lent itself in this case - and in many of the tests to follow - to the use of the χ^2 test of independence. The data are usually in frequency form and also in dichotomous categories such as S or V hypotheses. Even where dichotomous categories do not exist, it was meaningful to create at times such classes as above or below the median. The Yates correction of the formula was used (McNemar, 1955, formula 86a). The null hypothesis (Ho) was rejected when $\chi^2_{.05}$, 1 d.f. = 3.84 was surpassed.

> Ho: Animals do not differ in the number of hypotheses formed as a function of being above or below the median in BWC. (N = 31).

Result: $\chi^2 = 5.59$ and the Ho is rejected. Another indication of this relationship is given by η which has a value of .663 ($P < .001$). (The F ratio between η and r = 1.057 and linear regression may be assumed). It is concluded that the number of hypotheses formed is a function of BWC; more hypotheses are formed with severe losses of body weight and fewer hypotheses are formed with moderate increases of weight.

> Ho: That animals do not differ in forming S or V hypotheses predominantly as a function of being above or below the median in BWC.

In this test, N = 28 and animals forming <u>both</u> S and V hypotheses were included providing one type occurred with greater frequency. Eight animals were included from this mixed category and one was excluded.

<u>Result</u>: $\chi^2 = 5.89$ and the Ho is rejected. It is concluded that S hypotheses predominate with major negative BWC, and V hypotheses predominate with slight increases or decreases in body weight.

<u>Ho</u>: That animals do not differ in shifting or not shifting hypotheses as a function of being above or below the median in BWC.

Since 29 of the 31 animals formed hypotheses, N = 29. However, of these, only nine animals shifted hypotheses.

Results: $\chi^2 = 0.46$ and the Ho cannot be rejected. It should be noted from Figure 2 and from the results presented above that S hypotheses increase while V hypotheses decrease as the animals lose weight. Since shifting hypotheses involves by definition both V and S hypotheses, some restriction of this shifting within the more moderate levels of BWC might be expected. Inspection of the data in the Appendix, Table 9, reveals that six of these nine animals are above the median BWC. There are thus empirical grounds cautioning against acceptance of this Ho.

B. The effect of varying food and water.

The contamination of the type of deprivation by the level of deprivation prevented an adequate test of the effect of food and water on hypothesis behavior. Some indication of the effect may be gained by constructing roughly equivalent groups. Two such groups are the moderate FD and severe WD from the original design (note their similarity in Tables 3 and 5). Table 6 presents a comparison of these two groups and it will be seen that there is little difference in the frequencies.

TABLE 6

COMPARISON OF THE MODERATE FOOD DEPRIVED AND SEVERE WATER DEPRIVED GROUPS FOR FREQUENCIES OF DOMINANT HYPOTHESIS TYPE

Preference	Food	Water
Spatial	5	5
Visual	2	3

Matched groups can also be composed by choosing animals with nearly equivalent BWC. Unfortunately, these are too few to warrant statistical test but the data are presented in Table 7 for inspection. There is a slight indication that food deprivation may more likely be associated with S hypothesis formation than water deprivation.

TABLE 7

FOOD AND WATER DEPRIVED ANIMALS MATCHED FOR EQUIVALENT BODY WEIGHT CHANGE

BWC %		Number and Type Hypothesis				Trials to Solve AP	
Food	Water	Food		Water		Food	Water
		S	V	S	V		
- 5.7	+ 5.8	3	0	0	1	38	36
- 5.5	- 4.7	3	1	0	2	21	35
- 7.9	- 7.7	1	3	2	1	33	27
-18.5	-16.8	2	0	3	0	25	23
-31.2	-31.4	6	0	5	0	33	36

It will be shown in section C that BWC was not significantly related to the shifting of hypotheses. Since it therefore seems probable that motivation is not a contaminating factor, we may test the food and water deprivation variable on the shifting of hypotheses. The resulting χ^2 = .016 and the Ho is not rejected. The effect of this variable on the AP trials was also tested and χ^2 = .0039 and the Ho is not rejected. It is concluded that type of deprivation was related neither to the shifting of hypotheses nor to the ease of solving the adaptability problems. It was not possible to test the influence of deprivation type on the kind of hypotheses formed.

C. <u>The relation of hypothesis behavior to adaptability</u>.

Adaptive behavior was measured by the total number of trials to solve two problems. These problems (AP) were arrangements of the doors of the Krech apparatus such that one of the four hypotheses S right (SR) or left (SL), V light (VL) or dark (VD), was a correct solution. Each animal was presented with one of the S problems and one of the V problems, the order of presentation (S or V first) was determined by the experimenter who assigned roughly equal amounts of the orders to the various categories of hypothesis-forming animals.

It is possible that order effects exist in the presentation of these problems. If an animal had shown an SR preference or hypotheses the use of problems <u>S</u>L and <u>V</u>D in that order may have been more, or less, intrinsically difficult than the order <u>V</u>D, <u>S</u>L.

A second source of order effect might be found in the choice of the particular cue of each modality; that is, an S<u>R</u> (or V<u>D</u>) problem also might be more - or less - intrinsically difficult than S<u>L</u> (or V<u>L</u>) problems. However, this second order effect was controlled by giving all animals problems which differed from their last demonstrated preference (as revealed by the largest number of choices within the SR, SL, VL, VD categories). If an animal had shown SR and VD preferences during the hypothesis trials,

the problems presented would be SL and VL, although not necessarily in that order. Thus, the first type of order effect varied while the second type was partially controlled.

An indication of the effect of this first type of order can be obtained from the point-biserial correlation between order (first problem the <u>same</u>, first problem <u>opposite</u> demonstrated preference) and the distribution of number of trials on the AP. This correlation has the value $r_{pb} = .013$ which of course is not significant. When tested by χ^2, (Same-Opposite x More-Less median trials on the AP), $\chi^2 = .028$ and is not significant. Therefore it will be assumed that an order effect does not exist in the analysis of the data to follow.

Some statistics of the animals' gross behavior are presented in Table 8. It will be noted that more animals formed S hypotheses and more frequently, than any other

TABLE 8

TYPE AND FREQUENCY OF HYPOTHESIS BEHAVIOR

Number of Animals	Type of Hypothesis Formed	Mean Number of Days Persisted
14	S only	4.57
6	V only	2.67
9	Both S and V	4.11
2	none	--

category. This differs from Krech's finding and will be discussed in the next chapter. However, on the basis of his argument for adaptability there appears to be a logical basis for inferring that animals which form V hypotheses are more adaptive since S hypotheses are more "popular." The California group had stated that on the first five or six trials their animals displayed a decided preference for the lighted alleys (Rosenzweig, et al., 1958). Accordingly, the data from these trials were analyzed. The Spatial minus Visual Preference score was computed for the first six trials and found to average -2.4 per cent. This indicates that there may be a very slight general orientation of the animals to the light cues, light or dark. When the individual visual preferences are examined it is found that 13 preferred the lighted alleys to some degree. Thirteen of the animals also exhibited a preference for the darkened alleys, and for five of the animals the preferences were equal. When the data were examined for the most marked preference, S or V, it was found that 16 animals preferred S, 14 preferred V, and with one animal the choices were tied. Thus, it is not clear which category of hypotheses Krech would identify as the more adaptive on the basis of his line of argument. All alternatives will be tested.

> Ho: Animals forming only S hypotheses and all animals forming V hypotheses do not differ in

respect to being above or below the median in AP trials.

Result: $\chi^2 = .281$ and the Ho is not rejected. A test of the same type on V vs. S plus S and V frequencies yields a $\chi^2 = .0023$, and it is concluded that there is no evidence to identify either a V or S hypothesis factor with adaptability. The test may be applied to animals that shift hypotheses. (In this case, all animals that shifted hypotheses did so from one modality to another. None of the animals shifted within modalities.) The $\chi^2 = .016$ and the Ho is not rejected. It is concluded that there is no evidence to identify the shifting or non-shifting of hypotheses with adaptive behavior.

It may be argued that the more hypotheses an animal forms, the more adaptive that animal is. This proposition was tested by dividing the animals into categories above or below the median total number of hypotheses formed and above or below median number of trials on the AP. $\chi^2 = .152$ and the hypothesis is not rejected. It is concluded that there was no experimental basis for identifying frequency of hypothesis formation with adaptability.

In the recent publications of the California group, the implications of hypothesis behavior have been retained but the measure more usually relied on for the interpretation of the data has been the Spatial-Visual Preference Score (PS). The authors have equated a S preference as being more

innately adaptive. This may be tested by a correlation between each animal's PS and the trials on the AP. A significant negative correlation would indicate that V preferences are associated with few trials on the AP; positive correlations would associate S preferences with ease of solution. The correlation (r) between these two measures was -.013; this is taken as indicating no relation existed between an animal's PS and its adaptability. When the number of shifts in algebraic sign of the PS are correlated with the AP trials, $r = -.229$ which is not significant ($P > .10$).

To summarize the results of this section, no evidence was found in the present study to identify either type or amount or method of measuring hypothesis behavior with the measure of adaptive behavior (AP).

D. The effect of level of motivation on adaptability.

As will be noted from Figure 3, there is a general U-shaped relation between motivational level and AP trials; an optimal level appears to exist between a -10 per cent and -20 per cent BWC. The extent of this relation is given by the coefficient η which is .486 ($P > .10$) and by $r = -.275$ ($P > .10$). This also results in an insignificant χ^2. It is concluded that there is little statistical evidence for an optimal level of motivation for solving the AP, although a slight U-shaped relation is present.

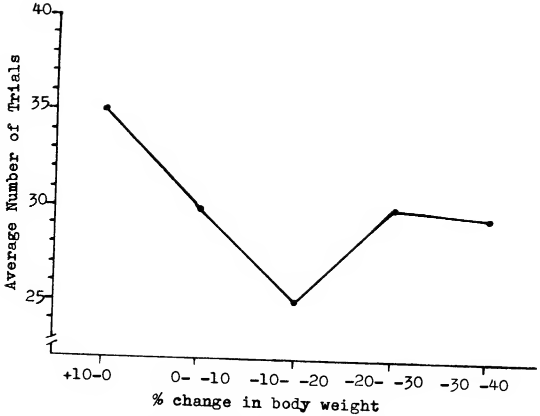

Fig.3.-The relation between body weight change and average number of trials to solve both adaptability problems.

CHAPTER IV

DISCUSSION

Consideration of the Experimental Hypotheses

A. Motivation and hypothesis behavior. One research hypothesis advanced earlier in this paper stated that the frequency, types, and shifts of hypothesis behavior would be some function of motivational level. The results have shown: (1) that an increase in motivational level, as measured by body weight change, was accompanied by an increase in the total number of days a hypothesis was exhibited; (2) that, while S and V hypotheses occurred with approximately equal frequency at the lower levels of motivation, V types declined but S types increased as motivational level increased; (3) that no statistically significant relation between motivational level and shifting of hypotheses was present, although six of the nine animals that did exhibit shifts were below the median in amount of body weight lost.

The effect of motivational level on hypothesis behavior had not been investigated prior to this study, and in neither the prior work of Krechevsky, nor in his more current work with the California group, has there been any

indication that these effects might exist. Particular forms of hypothesis behavior (S preferences and shifts in preference) were assumed by the California group to represent more adaptive behavior than V preferences and lack of shift in preference. Since shifts predominate at lower levels while S hypotheses predominate at higher levels of motivation, the results are apparently inconsistent with these assumptions. Rather, the present results indicate that such shifts in hypothesis behavior should more parsimoniously be related to motivational levels rather than to the relative adaptive level of some particular form of hypothesis behavior or the "adaptability" of the animal.

A second hypothesis stated that food and water deprivation would lead to different kinds of hypothesis behavior. This hypothesis proved to be untestable since the attempt to establish the required operationally equivalent motivational levels (measured by running speed and weight change) failed. This failure may be attributed to three causes. First, too small a sample of animals was used in the pilot study. Second, although it was not apparent from the pilot study, it now seems that the use of a percentage of <u>ad libitum</u> food or water intake does not produce sufficiently homogeneous running times or weight changes. Third, the relatively long period (about a month) of the deprivation schedule may have led to different effects within the food and water conditions.

The method which was utilized (reduced percentage of *ad libitum* intake) was an attempt to overcome certain difficulties of the traditional limited time schedules (water deprived rats may adjust their water intake to the amount of time available) and limited amount schedules (intakes and nutritional requirements vary partly as a function of age, body size, and metabolism). It now appears that sufficiently precise control would be obtained by reducing the body weight of each animal to some predetermined level *before* the start of the experimental program; this body weight level could be maintained by making daily adjustments in each animal's daily food or water ration.

B. *Hypothesis behavior and adaptability*. A third experimental hypothesis asserted a positive relationship between type and frequency of hypothesis behavior and adaptability (as measured by the trials to solve the adaptability problems, AP). In the present study no relation was found between the AP measure and total number of hypotheses formed, shifts in hypotheses, or types of hypotheses. This is a result which is in apparent opposition to the assumptions of Krech and his associates since a particular type of hypothesis behavior (spatial) and shifts in hypothesis behavior had been identified as "adaptive." There has not been any previous *empirical* evidence comparing hypothesis behavior with some other measure of adaptability.

These results may be interpreted to mean that hypothesis behavior is not a valid measure of adaptability. However, it is possible that the measure of adaptability, AP, used in the present study, is invalid. This is a crucial question, but since there is little precedent and no consensually agreed upon definition of adaptive behavior in the psychological literature, this point must at present be settled on logical grounds. Hypothesis behavior has been the major, but seldom used, convention for assessing this variable. While other measures - such as the Hebb-Williams apparatus - might have been used, the AP measure was chosen because it uses the same apparatus, procedure, criteria, and perceptual-motor capacities; equally important, its logic is congruent with Krech's reasoning that hypotheses are adaptive. It differs essentially in permitting a solution to take place. There exists such a high degree of similarity between hypothesis behavior and the AP measure, that the lack of any apparent relation between the two raises serious doubts as to the "adaptive" nature of hypothesis behavior. It also raises the question as to what hypothesis behavior is.

C. Motivation and trials to solve the two adaptability problems. A fourth hypothesis was advanced that adaptability would be related to motivational level. The results were

inconclusive; a U-shaped relation indicating an optimal motivational level (between -10 and -20 per cent BWC) was found but statistically significant correlations were not obtained. The concept of an optimal motivational level dates back to an original formulation by Yerkes and Dodson (1908). It has been found to be generally true in such studies as the Columbia obstruction box experiments (Warden, 1931), and more recently arousal level theorists have postulated a similar relation (Freeman, 1940; Duffy, 1957).

D. Conclusions. The relation of various hypothesis behavior measures to the solution of two problems has been examined and no support was found for the assumption that a particular type of hypothesis behavior can be considered intrinsically more adaptive than some other type. It has also been shown that the hypothesis behavior exhibited by an animal is a function of the animal's motivational level. It was therefore considered more parsimonious to relate these hypothesis behavior characteristics to motivational level rather than to assumed levels of adaptability. It was not possible to test the effects of food and water deprivation on hypothesis behavior since the attempt to establish operationally equivalent motivational levels in these categories was not successful. Finally, some evidence of an optimal level of motivation for performance was obtained but the evidence was not statistically significant.

CHAPTER V

SUMMARY

This study investigated relationships between: Krech's various measures of hypothesis behavior in the rat and adaptability, motivational level and hypothesis behavior, and motivational level and adaptability.

Thirty-one hooded rats were placed on limited food- or water-diets. After receiving trials to determine hypothesis behavior in the Krech insoluble maze, the animals were tested for adaptability by number of trials to solve two problems in the same apparatus.

The results indicated that:

1. There was no apparent relation between type, duration, or shifts in Krech's hypothesis behavior and the measure of adaptability.

2. The type of hypothesis behavior and its duration was a function of motivational level; hypothesis behavior which utilized light cues gradually diminished with increased body weight loss while hypothesis behavior based on spatial cues rapidly increased.

3. There was slight evidence of a curvilinear relation of adaptability to motivational level but it was not statistically significant.

4. It was not possible to determine differences in hypothesis behavior as a function of type of deprivation because of an inability to establish equivalent motivational levels.

The results were interpreted as evidence against Krech's assumptions that hypothesis behavior is adaptive. A motivational interpretation was considered to be the most parsimonious organization of the data.

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APPENDIX

TABLE 9

PER CENT BODY WEIGHT CHANGE, TYPE AND OCCURRENCE OF HYPOTHESES, AND TRIALS TO SOLVE THE ADAPTABILITY PROBLEMS

Per Cent Body Weight Change	Deprivation Condition Food (F) and Water (W)	Hypothesis Formed on Day Number	Order of Presentation and Trials to Solve Adaptability Problems		
			V	S	V
+ 9.7	70 W	VD 3; SR 7	19	23	
+ 5.8	70 W	VD 8	21	15	
+ 5.7	65 F	SL 1, 2, 3	18	20	
+ 3.1	70 W	VD 5, 6, 7, 8, 9		12	12
+ 2.4	70 W	none	13	12	
+ 2.2	70 W	SL 6, 7, 8, 9		30	18
+ 1.7	70 W	SR 5, 6; VD 7, 8, 9		18	21
+ 0.9	50 W	none		12	15
- 1.6	50 W	SR 2, 7		13	13
- 2.4	50 W	SL 5, 6		13	14
- 2.7	70 W	VD 4, 5; SR 9	25	11	
- 4.7	50 W	VD 5, 6	22	13	
- 5.5	65 F	SR 5, 8, 9; VD 7		11	10
- 6.8	50 W	VD 7, 8, 9		11	13
- 7.5	50 W	VD 4, 5, 8, 9	24	15	
- 7.7	70 W	VD 2; SR 6, 9		14	13
- 7.9	65 F	VD 3, 7, 9; SL 4	20	13	
-11.7	65 F	SR 3, 5, 6, 7; VD 9		12	15

Table 9 Cont.

Per Cent Body Weight Change	Deprivation Condition Food (F) and Water (W)	Hypothesis Formed on Day Number	Order of Presentation and Trials to Solve Adaptability Problems		
			V	S	V
-16.8	50 W	SL 3, 4, 5	11	12	
-18.5	65 F	SR 6, 8	13	12	
-20.5	65 F	VD 8		12	16
-21.7	65 F	SL 4, 5, 6, 7, 8, 9	12	13	
-23.1	45 F	SR 5, 6, 7, 8, 9	18	18	
-23.5	65 F	VD 3; SR 1, 7, 8, 9	16	17	
-25.3	45 F	SL 2, 3, 4, 6, 7, 8		10	14
-26.6	45 F	SL 4, 5, 6, 7, 8, 9	22	11	
-28.9	45 F	SR 3, 4, 5, 6; VL 7	18	13	
-31.2	45 F	SL 4, 5, 6, 7, 8, 9		16	17
-31.4	50 W	SR 3, 5, 7, 8, 9	18	18	
-33.6	45 F	SL 4, 5, 6, 7, 8, 9		12	13
-33.7	45 F	SL 2, 3, 4, 5, 6, 7, 8, 9	12	12	

BIOGRAPHICAL SKETCH

Robert Louis Procter was born March 26, 1928 in Washington, D. C. The son of a Naval Officer, he lived in Virginia, New York, California, and Massachusetts until his father's retirement in Vermont in 1937. He graduated from Springfield (Vt.) High School in 1945 and was accepted into the Army Specialized Reserve Training Program and assigned to Massachusetts State College. He was later transferred to Korea and then discharged from the Army in 1947. He was admitted to the University of Missouri in 1948 and received his B.A. degree in 1951 and his M.A. degree in psychology in 1953. He returned to the Army in that year and was discharged in 1955. He entered the University of Florida in 1955 and held a series of graduate assistantships, primarily in clinical and comparative psychology. He was also employed at Sunland Training Center, Gainesville, Florida, and Rome (New York) State School, where he was Senior Clinical Psychologist. His internship was at the Veterans Administration Hospitals in Gulfport and Biloxi, Mississippi. He is a member of Psi Chi, psychology honorary, and the Florida Psychological Association.

This dissertaion was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Arts and Sciences and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June 11, 1962

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